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# Effects of Site Preparation on Seedling Growth: A Preliminary Comparison of Broadcast Burning and Pile Burning

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## Abstract

Site preparation is often necessary to obtain adequate forest regeneration, but inappropriate treatment may reduce subsequent growth. Broadcast-burned and piled-and-burned plantations were studied in southwestern Oregon to determine if burning method affected the growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*). The measured and potential heights of 5-year-old seedlings were about equal where broadcast burning occurred, but measured heights were less than potential heights on most of the piled-and-burned plantations. Site quality probably is damaged by piling and burning.

Keywords: Site preparation (-regeneration, seedling growth, plantations.

## Introduction

Site preparation is desirable and necessary to establish conifer regeneration on most sites in Oregon (Stewart 1978). The environmental modification resulting from that site preparation usually benefits seedling survival, and higher stocking levels usually are achieved (Wilhite 1981). The environmental conditions that favor high stocking levels are not necessarily the same as the conditions that favor vigorous seedling growth, however, and seedling growth may be reduced if inappropriate site-preparation treatments are applied.

Windrowing of slash is sometimes an inappropriate site-preparation treatment. It reduced the growth of loblolly pine between windrows where topsoil had been removed by rootraking in North Carolina (Glass 1976). A similar windrowing effect occurred in northern California with white fir (*Abies concolor* var. *lowiana* (Gord.) Lemm.), despite attempts to respread the windrows, and even though brush competition was greater in the windrows than between them, where topsoil had been removed (Nakamura 1985). The removal of topsoil, litter, and humus is a major loss to the site that can have long-term negative effects on productivity (Austin and Baisinger 1955, Terry and Campbell 1981). Such loss is not limited to windrowing; it also occurs during several other site-preparation treatments.

Soil compaction occurs during several site-preparation treatments. Compaction may sometimes be beneficial where moisture is limiting and aeration is adequate (Lull 1959), and moderate compaction may not seriously affect plant nutrient status where moisture conditions remain satisfactory in fertile soils (Kemper and others 1971). Soil compaction is detrimental under most conditions, however, and the compaction that occurs during logging and slash disposal has a negative effect on

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most sites. It reduces water infiltration (Tackle 1962), increases soil strength, and impedes root penetration (Heilman 1981, Minore and others 1969, Taylor and Burnett 1964), and reduces seedling growth (Foil and Ralston 1967, Steinbrenner and Gessel 1956). The major effect of compaction on tree growth appears to occur during the first 10 to 30 years (Power 1974), but severely affected soils may not recover for 30 to 40 years or longer (Perry 1964, Power 1974, Wert and Thomas 1981).

The effects of slash burning do not seem to last as long as the effects of soil compaction. Severely burned areas are difficult to regenerate (Stewart 1978), however, and poor seedling growth has been associated with heavily burned soils (Baker 1968). Burning decreases the subsequent number of mycorrhizae on Douglas-fir seedlings (Wright 1971), but the resulting ash acts like a slow-release fertilizer on deep soils with sufficient cation-exchange capacity to absorb the nutrients that are released (Stark 1979). The direct effects of burning logging slash are usually confined to the top 5 cm (2 in) of soil depth (Austin and Baisinger 1955). Fertile, usually moist soils are less damaged by fire than infertile, dry soils (Jablanczy 1964).

Soil fertility, moisture, and drainage influence the effects of site preparation, and differences among site preparation treatments are often obscured by differences in site quality when those treatments are compared. For example, plant response to soil compaction varies with soil type, plant species, and climate (Rosenberg 1964), and the effects of compaction on nutrient uptake vary with fertility, root distribution, and moisture and aeration regimes (Parish 1971). Harvest intensity and slash removal tend to have greater effects on seedling growth and mortality where productivity is low than they do where productivity is high (Bigger and Cole 1983). Variation within a given treatment is also influenced by productivity of the site because among-plot variability in soil properties tends to be higher on high sites than it is on low sites (Courtin and others 1983).

Commonly used site-preparation treatments are almost as variable as the sites on which they are applied. Most clearcut areas are yarded by cable or tractor, but these yarding methods are combined with subsequent slash treatments that include broadcast burning, piling and burning on site, and piling and burning off site. Soil compaction is sometimes ameliorated by tilling (disking or ripping). High-intensity treatments accomplished with heavy equipment are more costly than low-intensity treatments (Mills and others 1985), and whether the extra money spent to obtain better seedling survival also results in better seedling growth is important to determine. If intensive site preparation degrades the site and results in poorer growth, the investment in site preparation may be buying initial stocking at the cost of subsequent growth.

I am conducting a long-term study to determine the effects of various site preparation treatments—yarding, slash disposal, and tilling (when present)—on seedling growth in southwestern Oregon. Many plantations on many different sites will be measured to obtain replicates of each treatment-combination on several sites, and each combination will be analyzed to determine its effect on growth. Data will be collected for several years to obtain the requisite number of plantations for these detailed analyses.

Presently available data do not permit detailed analyses of each treatment combination, but they do allow a preliminary comparison of two commonly used slash-burning treatments. That comparison is presented here. My objective is to determine if broadcast burning and piling and burning have different effects on the growth of seedlings planted in clearcut areas

## Methods

Data were collected on 57 progeny test plantations in Coos, Curry, and Douglas Counties, Oregon, during 1984. Plantation selection was based on the availability of 5-year seedling-height data. Federal and private members of the Coquille, Gold Beach, and Roseburg Tree Improvement Cooperatives owned the plantations, which were fenced to keep out browsing mammals and carefully tended to control brush competition. Each plantation was about 4 ha (10 ac), and each contained several thousand carefully planted, individually identified Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) seedlings of known female parentage. Heights were measured when the seedlings were 5 years old from seed. The average 5-year seedling height measured on each plantation was obtained from records stored at the Forestry Sciences Laboratory in Corvallis, Oregon.

A potential 5-year seedling height was determined for each plantation by using the method described by Minore (1986). Stumps of the best-growing trees from the previous stand were measured on each plantation and used in a regression equation to estimate the potential seedling height that would be obtained on the site after minimal disturbance. This potential seedling-height estimate was a function of site quality, not site preparation or slash burning technique. It was used to reduce the confounding effect of site quality when slash burning techniques were compared among plantations.

Slash was treated by broadcast burning on 23 of the progeny-test plantations (fig. 1). On the other 34 plantations (fig. 2), slash was piled and burned. The two burning treatments were not uniform or consistent, however, and burning was only one factor in site preparation. Plantations in the broadcast-burned category included some that were cable-yarded and some that were tractor-yarded. The piled-and-burned category also included both cable- and tractor-yarding and included some plantations where burning was done off site and some where piles were burned on the plantation. Most of the piling was done by machine, but a few plantations were hand piled. The number of plantations measured in 1984 was insufficient to differentiate these more detailed categories in this preliminary comparison.

Seedling heights after broadcast burning were compared with seedling heights after piling and burning by comparing potential heights with measured heights in each burning category, by two methods:

- A potential-minus-measured-height difference was determined for each plantation, and the average difference was calculated for each burning treatment. These average differences were then compared to see which treatment was associated with the largest difference.

- Potential height was plotted against measured height on a set of coordinates. A separate graph was used for each burning treatment, and the resulting plots were compared to see which treatment was associated with the greatest divergence from a 45° line that expressed axis equality (potential height = measured height).

Soil compaction was measured indirectly by sampling with a proving ring penetrometer to determine the average soil-penetration resistance on each plantation. Penetration resistance in the top 20 cm (8 in) was determined at 100 to 400 systematically located points on each plantation. A grating sound and harsh feel were produced when the penetrometer probe was pushed against rocks, and penetrometer readings influenced by rocks in the soil profile were discarded. Rock-free and rocky measurements were not differentiated at first, however, and the

Figure 1—A progeny-test plantation established after slash had been broadcast burned. Note the scattered debris and charred stumps. Most plantations were not this steep.

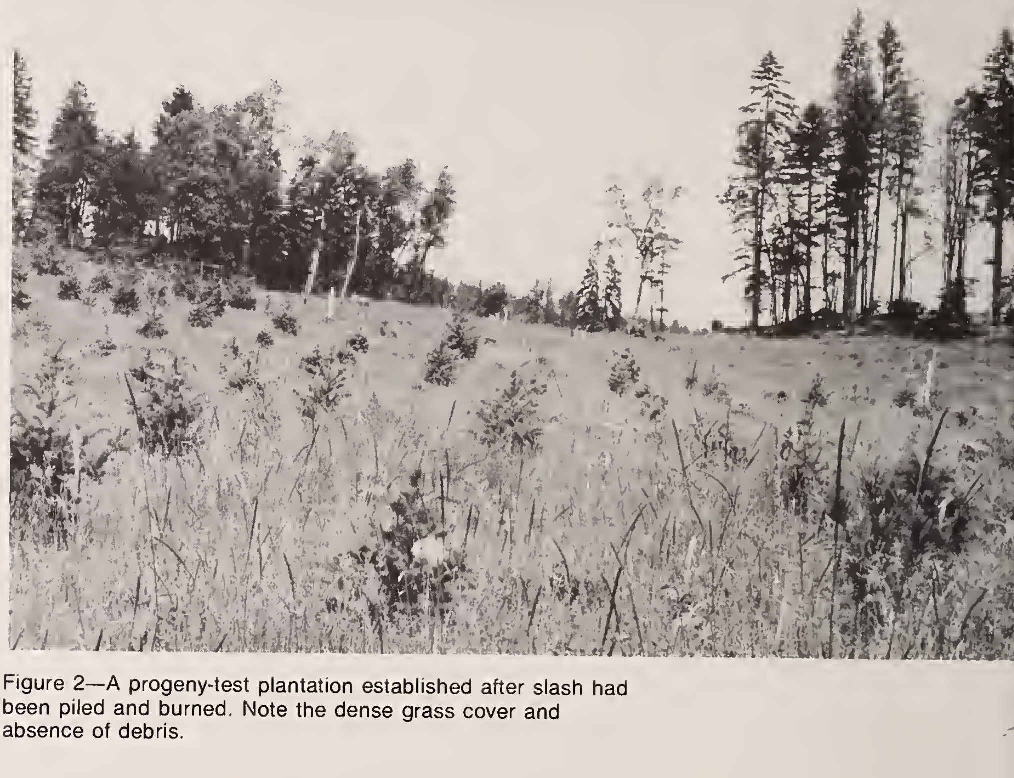

Figure 2—A progeny-test plantation established after slash had been piled and burned. Note the dense grass cover and absence of debris.

presence of rocks was not recorded until June 1984. Therefore, penetrometer measurements recorded before June were not used in comparing soil-penetration resistance among plantations. Penetrometer readings below 3.5 kg per $cm^2$ (50 lb per $in^2$) were judged to be the result of hidden holes or animal burrows.

Soil structure, texture, and moisture influence soil-penetration resistance measured with a penetrometer (Lutz 1952). The plantations occurred on soils of various structure and texture, and because they were measured throughout the summer under various moisture conditions, I adjusted the penetrometer measurements for these differences. I assumed that 1 percent of every plantation remained unaffected by the soil compaction associated with logging or site preparation and calculated a mean soil-resistance value for the lowest 1 percent of the rock- and hole-free penetrometer measurements obtained on each plantation. This low mean value was used as an adjustment factor by subtracting it from the mean of all the rock-free penetrometer measurements on that plantation:

$$\text{Adjusted resistance} = (\text{mean of all } P_{rf}) - (\text{mean of lowest 1\% } P_{rhf}),$$

where $P_{rf}$ = rock-free penetrometer measurements, and

$P_{rhf}$ = rock- and hole-free penetrometer measurements.

Penetrometer measurements were higher on dry sites than on moist sites, but the mean value of the lowest 1 percent of the rock- and hole-free measurements was also higher on dry than on moist sites. Subtracting the low mean from the total mean provided an internal soil calibration for each plantation that resulted in a soil-penetration resistance value that was assumed to be corrected for soil structure, texture, and moisture.

The presence or absence of humus in the top 20 cm (8 in) of soil was determined at every penetrometer sampling point by examining the soil on the flat top of the penetrometer cone after each soil resistance measurement. Humus frequency was calculated for each plantation by summing the number of sample points containing humus and dividing that sum by the total number of points. The result was multiplied by 100 to convert to a percentage:

$$\text{Humus frequency \%} = \frac{\text{number of points with humus}}{\text{total number of points}} \times 100.$$

## Results and Discussion

Seedling heights varied greatly among plantations, both within site-preparation treatments and between treatments. This variation occurred with potential heights as well as with seedling heights actually measured on those plantations. Differences were apparent between the two site-preparation treatments, however, in spite of the variation within each treatment (tables 1 and 2).

## Table 1—Potential seedling height, measured seedling height, soil-humus frequency, and soil-penetration resistance on plantations where slash was broadcast burned

| Plantation | Potential seedling height[1] | Measured seedling height[2] | Potential-measured height difference[3] | Soil-humus frequency[4] | Soil-penetration resistance[5] |
|---|---|---|---|---|---|
| | Centimeters[6] | | | Percent | Kilograms/ square centimeter[7] |
| I | 148.5 | 152.6 | -4.1 | 100.0 | — |
| II | 185.4 | 198.8 | -13.4 | 52.5 | 14.2 |
| III | 79.8 | 62.8 | +17.0 | 81.9 | 7.7 |
| IV | 89.1 | 67.9 | +21.2 | 69.3 | 15.0 |
| V | 106.2 | 97.9 | +8.3 | 48.8 | 13.8 |
| VI | 122.0 | 119.9 | +2.1 | 84.6 | — |
| VII | 105.2 | 89.5 | +15.7 | 39.4 | 10.2 |
| VIII | 64.4 | 69.0 | -4.6 | 52.6 | 12.2 |
| IX | 94.8 | 98.6 | -3.8 | 98.9 | 10.3 |
| X | 73.0 | 98.9 | -25.9 | 90.0 | 10.0 |
| XI | 73.0 | 91.6 | -18.6 | 63.7 | 13.6 |
| XII | 89.8 | 76.0 | +13.8 | 88.5 | 7.6 |
| XIII | 59.0 | 56.4 | +2.6 | 68.2 | 4.7 |
| XIV | 66.2 | 57.3 | +8.9 | 79.5 | 4.4 |
| XV | 163.9 | 144.9 | +19.0 | 34.7 | — |
| XVI | 112.3 | 111.7 | +0.6 | — | — |
| XVII | 128.4 | 180.0 | -51.6 | 59.8 | 8.8 |
| XVIII | 136.3 | 136.2 | +0.1 | 60.6 | — |
| XIX | 119.9 | 99.1 | +20.8 | 53.8 | — |
| XX | 73.3 | 50.4 | +22.9 | 26.7 | — |
| XXI | 98.7 | 106.1 | -7.4 | 85.7 | — |
| XXII | 81.6 | 58.1 | +23.5 | 76.9 | 11.3 |
| XXIII | 93.7 | 95.0 | -1.3 | 77.1 | — |
| Average, all plantations: | 102.80 | 100.81 | +1.99 | 67.87 | 10.27 |
| n | 23 | 23 | 23 | 22 | 14 |
| standard error | 6.90 | 8.31 | 3.74 | 4.36 | 0.90 |

[1] Potential seedling height at 5 years was estimated by using a regression equation and measurements of stumps from the previous stand.

[2] The average of several thousand measurements of 5-year-old seedlings

[3] Potential height minus measured height.

[4] $\frac{\text{Number of sample points with humus in the top 20 cm}}{\text{Total number of sample points}} \times 100.$

[5] Penetration resistance was adjusted for soil-moisture differences among plantations by using the average of all rock-free penetrometer measurements on each plantation minus the average of the lowest 1 percent of the rock-free, hole-free measurements. Dashes indicate plantations where rock-free penetrometer measurements were not differentiated from measurements influenced by rocks.

[6] To convert to inches, multiply by 0.394.

[7] To convert to pounds per square inch, multiply by 14.223.

## Table 2—Potential seedling height, measured seedling height, soil-humus frequency, and soil-penetration resistance on plantations where slash was piled and burned

| Plantation | Potential seedling height [1] | Measured seedling height [2] | Potential-measured height difference [3] | Soil-humus frequency [4] | Soil-penetration resistance [5] |
|---|---|---|---|---|---|
| | ---------------- Centimeters [6] | | ---------------- | Percent | Kilograms/ square centimeter [7] |
| XXIV | 126.3 | 76 1 | +50.2 | 67.5 | 12.5 |
| XXV | 110.2 | 94.9 | +15.3 | 61.0 | 11.2 |
| XXVI | 89.1 | 95.4 | -6.3 | 76.6 | 14 6 |
| XXVII | 111.3 | 95.3 | +16 0 | 53.7 | 15.2 |
| XXVIII | 94.8 | 90.4 | +4.4 | 68.1 | 13.8 |
| XXIX | 103.8 | 75.7 | +28.1 | 35.5 | 14.0 |
| XXX | 139.9 | 53.7 | +86.2 | 44.3 | 12.4 |
| XXXI | 86.2 | 78.5 | +7.7 | 92.2 | 12.2 |
| XXXII | 89.1 | 73.1 | +16.0 | 85.2 | 12.2 |
| XXXIII | 139.2 | 65.7 | +73.5 | 27.8 | 14.0 |
| XXXIV | 117.4 | 59.4 | +58.0 | 89.7 | 9.1 |
| XXXV | 117.4 | 72.3 | +45.1 | 100 0 | 15.6 |
| XXXVI | 100.9 | 67.3 | +33.6 | 57.4 | 16.3 |
| XXXVII | 90.5 | 72.7 | +17.8 | 96.2 | 7.9 |
| XXXVIII | 177.1 | 99.7 | +77.4 | 36.5 | 13.1 |
| XXXIX | 196.8 | 119.1 | +77.7 | 40.5 | 14.2 |
| XL | 130.6 | 108.8 | +21.8 | 79.1 | — |
| XLI | 122.7 | 116.1 | +6.6 | 41.0 | 13.3 |
| XLII | 140.3 | 110.7 | +29.6 | 82.6 | 12.6 |
| XLIII | 103.4 | 103.9 | -0.5 | 69.2 | — |
| XLIV | 90.5 | 123.8 | -33.3 | 68.4 | — |
| XLV | 119.9 | 75.9 | +44.0 | 83.2 | — |
| XLVI | 105.9 | 92.9 | +13.0 | 64.6 | — |
| XLVII | 88.0 | 94.8 | -6.8 | 68.3 | — |
| XLVIII | 90.1 | 78.2 | +11.9 | 50.0 | — |
| IL | 137.4 | 70.3 | +67.1 | 19.6 | 10.6 |
| L | 103.4 | 83 1 | +20.3 | 51.0 | 13.9 |
| LI | 147.1 | 63.2 | +83.9 | 92.7 | 10.9 |
| LII | 81.6 | 62.0 | +19.6 | 66.0 | 8.2 |
| LIII | 82.3 | 63.1 | +19.2 | 87.6 | 8.0 |
| LIV | 100.5 | 72.0 | +28.5 | 40.6 | 15.4 |
| LV | 118.1 | 91.9 | +26.2 | 89.9 | — |
| LVI | 90.9 | 85.4 | +5.5 | 59.5 | 12.9 |
| LVII | 96.2 | 60.9 | +35.3 | 68.1 | 16.0 |
| Average, all plantations: | 112.91 | 83.71 | +29.19 | 65.10 | 12.70 |
| n | 34 | 34 | 34 | 34 | 26 |
| standard error | 4.57 | 3.20 | 4.92 | 3.64 | 0.48 |

[1] Potential seedling height at 5 years was estimated by using a regression equation and measurements of stumps from the previous stand.

[2] The average of several thousand measurements of 5-year-old seedlings.

[3] Potential height minus measured height

[4] $\frac{\text{Number of sample points with humus in the top 20 cm}}{\text{Total number of sample points}} \times 100$

[5] Penetration resistance was adjusted for soil-moisture differences among plantations by using the average of all rock-free penetrometer measurements on each plantation minus the average of the lowest 1 percent of the rock-free, hole-free measurements. Dashes indicate plantations where rock-free penetrometer measurements were not differentiated from measurements influenced by rocks.

[6] To convert to inches, multiply by 0.394.

[7] To convert to pounds per square inch, multiply by 14.223

Potential seedling heights ranged from 59 to 185 cm (23 to 73 in) on the broadcast-burned plantations, averaging 102.8 cm (40.5 in). Potential heights ranged from 81 to 197 cm (32 to 78 in) on the piled-and-burned plantations, averaging 112.1 cm (44.1 in).

Actual seedling heights measured in the field ranged from 50 to 199 cm (20 to 78 in) on the broadcast-burned plantations, averaging 100.8 cm (39.7 in). Field-measured heights ranged from 53 to 124 cm (21 to 49 in) on the piled-and-burned plantations, averaging 83.7 cm (33.0 in).

The differences between potential and measured heights also varied greatly among plantations, but those differences tended to be much larger on the piled-and-burned plantations than on the broadcast-burned plantations. By chance, inherent site quality (expressed here as potential seedling height at 5 years) tended to be higher on the piled-and-burned plantations than on the plantations that were broadcast burned. Actual growth in seedling height measured on the piled-and-burned plantations was less than growth measured on broadcast-burned plantations, however, indicating that piling and burning may be more detrimental to seedling height growth than broadcast burning.

Detrimental effects associated with piling and burning are also indicated when potential and measured heights are compared on each plantation. Measured and potential seedling heights were about equal on the broadcast-burned plantations, and the plotted data points are uniformly scattered around the 45° line of equality (fig. 3). In contrast, measured heights were less than potential heights on most of the piled-and-burned plantations, and most of the data points are below the 45° line (fig. 4).

The frequency of soil humus in the top 20 cm (8 in) was extremely variable, and little difference in humus was found between burning treatments. Soil-penetration resistance also varied in both burning treatments, and the higher average resistance measured on piled-and-burned plantations may be a sampling artifact (tables 1 and 2).

When more plantation data become available, the yarding and slash treatment procedures included in the two slash-burning categories discussed here will be analyzed and compared in six separate site-preparation categories:

- cable-yarded and broadcast burned
- cable-yarded and piled and burned on site
- cable-yarded and piled and burned off site
- tractor-yarded and broadcast burned
- tractor-yarded and piled and burned on site
- tractor-yarded and piled and burned off site

Less variation within treatments and greater differences among treatments should result.

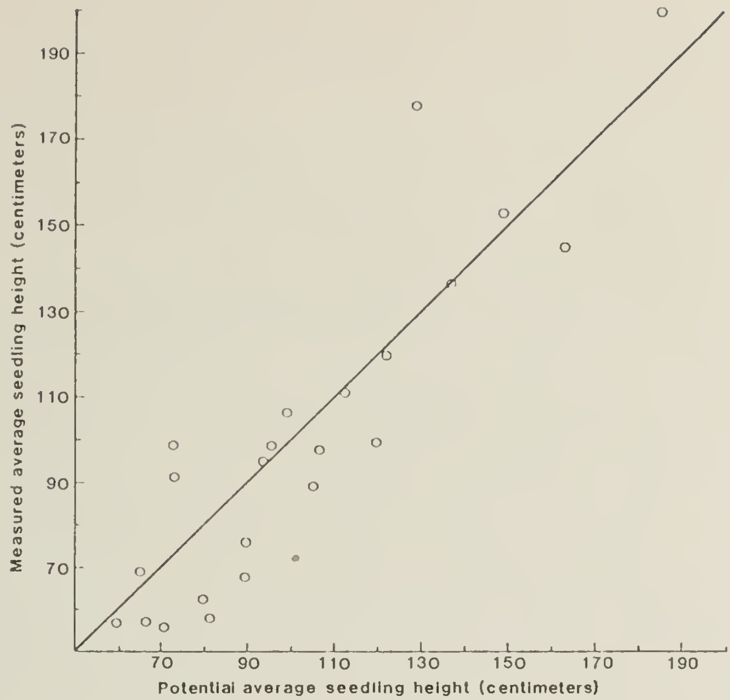


Figure 3—A comparison of measured seedling heights and potential seedling heights on plantations where slash was broadcast burned. Points below the diagonal line indicate measured heights shorter than potential heights at age 5. Points above the line indicate measured heights taller than potential heights.

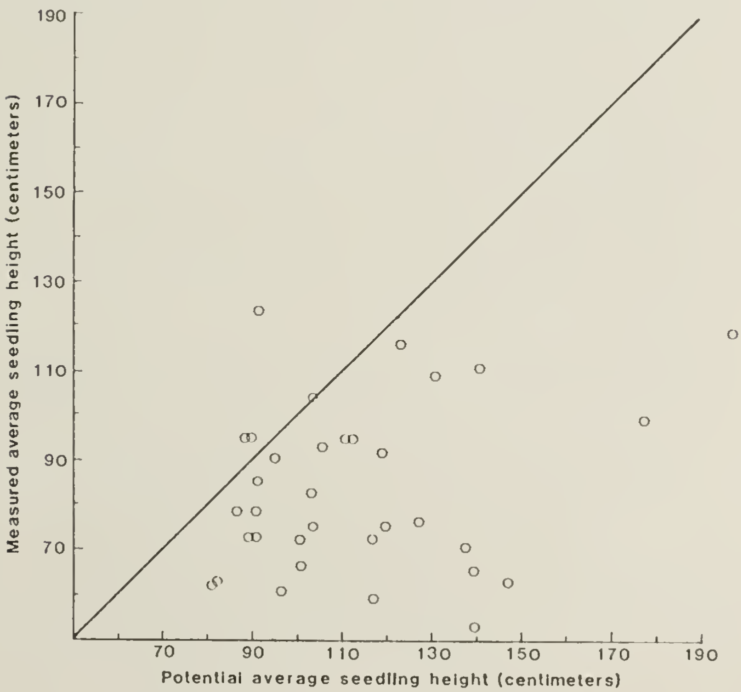


Figure 4—A comparison of measured seedling heights and potential seedling heights on plantations where slash was piled and burned. Points below the diagonal line indicate measured heights shorter than potential heights at age 5. Points above the line indicate measured heights taller than potential heights.

The data presented here indicate that piling and burning slash tends to be associated with less seedling height growth than does broadcast burning in southwestern Oregon. Burning treatments are not isolated, however, and other factors (e.g., yarding equipment and season) may be responsible for the observed differences in seedling growth. I did not measure those factors; instead, I considered them to have random effects that increased variation among plantations without obscuring the effects of the two burning treatments being compared. If that is true, piling and burning slash tends to be damaging, and it probably degrades site quality as expressed in 5-year seedling height. Broadcast burning seems to be less damaging, and it may not adversely affect site quality.

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